A STUDY ON EXTRUSION OF MULTIPLE MATERIAL BONDING FOR FUSED DEPOSTION MODELING

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ABSTRACT

Fused Deposition Modeling (FDM) is an additive manufacturing process by which a 3D object is created from plastic filament.Single extruder is commonly used nowadays,but there are several researcher in company had make a inovation to this technology which are the two extruder can print with two material and colors. This concept of this development are developed by several manufacturers such as *Flashforge ,Leapfrog, Marketbot, Duplicator* and other machines that have been developed by using multiple extrusion and two type materials. The study is focusing on the cabality of singning and joining two different material that often used in the RP especially foor FDM method which are PLA and ABS material. Each of the materials have the different temperature for bed and print. Hence, the main strength of this project is to identify, evaluate and do analysis on the joining of different materials in one sample or product by using the dual extrusion of machine. Two type of joining are used in this study which are Butt joint and Lap joint. The paramater used are Infill,air gap and raster angle is fixed to 10%,spare and 45/-45. Sample for tetsing will follow the ASTM638 Tensile test and Iso 718 for flexural test. Flexural test,ABS and PLA is the most flexural compared to others,whice are maximum value Force is 65N and for strok is 7.5mm,and for the tensile test ABS and ABS with butt joint are the most high value which are maximum value for Stress 27MPA and for the strain is 5%. The result show that combination of PLA with ABS are not so similar with the combination of ABS and ABS. The result is based on the data by using UTM machine.

ABSTRAK

Pemodelan Endapan Terlakur (FDM) adalah satu proses pembuatan bahan tambahan lapisan demi lapisan dalam membuat objek 3D dari filamen plastik. Filamen ditolak melalui muncung panas di mana ia akan cair kerana proses pemanasan. Lapisan deposit muncung plastik akan mencair selepas filamen dipanaskan. Sehingga hari ini FDM hanya boleh membuat produk bahan tunggal atau sampel. Namun Baru-baru ini, beberapa pencetak telah dihasilkan yang mana ia mempunyai pelbagai extruders, yang membolehkan objek yang hendak dibentuk menggunakan pelbagai bahan lain atau warna. Konsep pembangunan ini dibangunkan oleh beberapa pengeluar seperti *Flashforge, Leapfrog, Marketbot, duplicator* dan mesin-mesin lain.Teknologi ini telah dibangunkan dengan menggunakan dua penyemperitan dan dua jenis bahan. Kajian ini memberi tumpuan kepada kebolehan dalam process penyatuan diantara dua bahan yang berbeza yang sering digunakan dalam RP (Rapid prototyping) terutama didalam kaedah FDM (pemodelan endalam terlakur) yang mana bahan ia adalah PLA dan ABS. Setiap bahan mempunyai suhu yang berbeza, Oleh itu, kekuatan utama projek ini adalah untuk mengenal pasti, menilai dan melakukan analisis mengenai penyatuan bahan yang berbeza dalam satu sampel atau produk dengan menggunakan penyemperitan dua mesin. Dua jenis kaedah sambungan yang digunakan dalam kajian ini ialah sambungan *'Butt'* dan '*Lap*'. Paramater yang digunakan adalah *infill*, *air gap* dan *raster angle* yang mana masing-masing adalah tetap nilainya kepada 10%, spare dan 45 / -45. Contoh untuk kajian ini akan mengikuti ujian ketetapan ASTM638 untuk kajian tegangan dan ISO 718 untuk ujian lenturan. Ujian lenturan, ABS dan PLA adalah yang paling lentur berbanding dengan yang lain, yang mana nilai tetrtinggi adalah 65N dan untuk strok adalah 7.5mm, dan untuk ABS dan ABS dengan jenis sambungan 'Butt'adalah nilai yang paling tinggi iaitu nilai maksimum untuk Tekanan 27MPA dan untuk terikan adalah 5%. Ini menunjukkan bahawa gabungan PLA dengan ABS tidak begitu jauh nilai diantara ABS dan ABS. Hasil keputusan makmal ini diambil dari pangkalan data dengan menggunakan mesin UTM.

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LIST OF ABBREVIATIONS

3D	-	Three Dimensional
3DP	-	Three Dimensional Printing
CAD	-	Computer Aided Design
FDM	-	Fused Deposition Modeling
PS	-	Projek Sarjana
RP	-	Rapid Prototyping
STL	-	Standard Triangulation Language
UV	-	Ultra Violet
PLA	-	Polylactic Acid
PLV	-	Polyvinyl Alcohol
ASTM	-	American Standard Testing Machine
SEM	-	Scanning Electron Microscope
TCP	-	Tricalcium Phosphate
ABS	-	Acrylonitrile Butadiene Styrene
UTM	-	Universal Testing Machine
MPa	-	Megapascal

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CHAPTER 1

INTRODUCTION

1.1 Rapid prototyping

Rapid Prototyping also known as RP to the manufacturing industry open a new dimension to producing a product. RP has generated much interest the area of engineering and manufacturing as this technology, which has a unique layer by layer manufacturing methods, enables time and cost saving associated with model making. Many types of product can be produce by RP in shorter time than using the conventional process. By the RP come in the industry, more competition comes from the manufacturer. To improve the RP system and many researcher studies of RP was done until now.

However, this layer by layer manufacturing is not yet in widespread use, especially in Malaysia, as it is still a relatively modern technology. Known as brand new technology, RP must be developing in Malaysia. This is an important to the local manufacturer to produce their product with high quality from the economic cost and shorter lead time. The user of RP enables the companies from Malaysia more competitive with the international company that will attract more investors come to Malaysia as Technology Centre.

Rapid prototyping is the fabrication of parts from CAD data sources. Several rapid prototyping methods have been created to produce objects of complex geometries in a relatively short amount of time. These systems are beneficial to engineers by allowing then to better understand the products that they are designing

and by providing them with a way to create a visual aid to communicate with others. Rapid prototyping allows design challenges to be determined earlier in the design process, saving time and money. The technology of rapid prototyping is easy to access and simple to understand.

Rapid prototyping is a form of manufacturing where the materials are added layer by layer to definite points in space to build up a solid part. This type of technology is often referred to as also layered manufacturing, rapid manufacturing or additive fabrication. During the beginning stages of use of this technology it was mainly used to build smaller models or prototypes of new products or products being developed but due to their much wider range of applications, they are now being used in different fields. They range in various sizes depending upon their need and quality desired. They are also suited when high quality parts have to be made for relatively small numbers. Rapid prototyping involves a process in which a 3D model of the desired part is built layer by layer through the process of additive fabrication. Modeling software such as Solid works or other animation software can be used for the purpose of modeling which is then converted into thin slices.

The sliced file has all the information of the specific points which are the shape and geometry of that particular slice or layer. These slices when stacked one on top of the other will encompass the whole part. Charles W Hull was the first to create a unique method of Rapid prototyping [1], which later became available to others as this form of technology grew and more people wanted to build prototypes and models for testing and evaluation purposes. Rapid prototyping finds itself of use in a wide range of industries such as Aerospace, Military, Consumer products but so far is majorly adopted by the motor vehicle industry. The typical design process in Rapid prototyping is as follows – Concept, Preliminary Design, Preliminary fabrication, Test Production and then Final production.

1.2 **Conceptual of FDM**

Fused deposition modeling is an additive manufacturing (AM) process which produces parts from thermoplastic filaments. The build and support materials are a continuous filament held on a spool that is fed through heated extrusion nozzles. The

FDM head contains two nozzles, one for support material deposition and the other for the build material. The material is heated to a semi-liquid state as it passes through the extrusion head, which is controlled by an X and Y motion control as shown in figure 1. The nozzle extrudes material as it follows the contours in the x-y plane based on the program generated by the CAD model.

Once a layer is complete the build table moves in the z direction one layer thickness for the next layer to begin. This process is repeated for each layer until the final build height is reached. Water soluble support material, if used, may then be removed by placing the structure into a water bath. The support material is designed to be mechanically weak so that it can be broken off from the finished part at the end of the process. The part materials have been different ABS polymers (available in colors), an investment casting pattern wax, and a new elastomeric material. [2]

FDM was developed and patented in the year 1898 by Scott crump. Immediately after in 1990, he then setup Stratasys, a company which now specializes in manufacturing of additive fabrication machines for direct digital manufacturing .In 2007, almost half the amount of all fabrication systems worldwide was supplied by Stratasys making it a consecutive 6^{th} time market leader. FDM in its working is quiet similar to the other rapid prototyping systems in which a STL file is fed into the fabrication machine which then builds the model layer by layer.[3]

Now a day has been more conceptual of Fused Deposition Method, and some of the ideas associated with a no-growth economy turned out to be a booming growth industry. That previously had in the market. The idea of three-dimensional printers who involve Fused Deposition Method is not a new concept and indeed, there were formerly examples of related techniques in operation and machine that advance then the existing FDM machine such as, *flashforge Leapfrog, Markerbot, Duplicator* and some other machine that widely growth in RP industry using the same technique of FDM. The main difference between existing SFF technology and other's machine is the cost and adaptability of the machine FDM and 3DP are extremely expensive and greatly limited to the materials they are designed to work with. With the machine of this innovation, *Leapfrog, Marketbot, Duplicator* will, are possible to lack the cost and time. As FDM are the main topic of this research, it will be discussed in full detail in the following next sections.

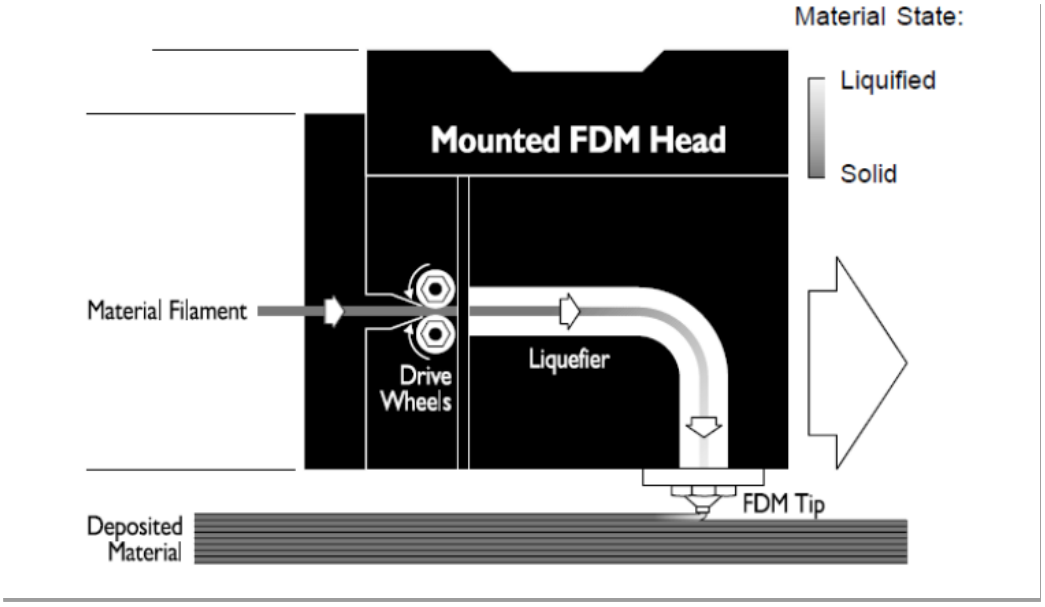


Figure 1.1: The Schematic showing the basic FDM process

1.3 Problem Statement

Fused Deposition Modeling (FDM) is an additive manufacturing process by which a 3D object is created from plastic filament. The filament is pushed through a hot nozzle where it melts. The nozzle deposits plastic layer after layer to create the final object. Until today FDM can only fabricate single material product or sample. Recently, several printers feature multiple extruders, allowing objects to be formed from multiple materials or colors. The extruders are mounted side by side on the printer carriage as shown in Figure 1.2. The concept of this development are developed by several manufacturers such as *Flashforge ,Leapfrog, Marketbot, Duplicator* and other machines that have been developed by using multiple extrusion and two type materials.

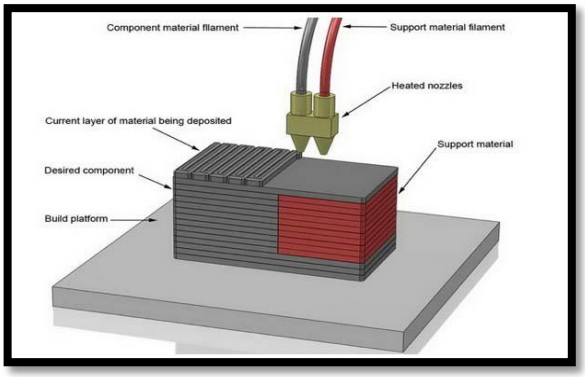


Figure 1.2: The schematic of FDM two nozzle and two material

Therefore combination or bonding between materials is one the issues that we can study. The common materials used are ABS, PLA, PVA and some others material. Each of the materials have the different temperature for bed and print. Hence, the main strength of this project is to identify, evaluate and do analysis on the joining of different materials in one sample or product by using the dual extrusion of machine based on flashforge Creator X 3d printing machine.

1.4 Objective

The objective of this study is:

a. To analyze and evaluate the capability of assigning two materials or heterogeneous materials in product.
b. To measure the mechanical properties of joining strength parts with heterogeneous materials.

1.5 Scope of study:

1. To evaluate only two different of material to fabricate the product or sample, (PLA and ABS).

2. To do mechanical properties assessment on
   i. Tensile strength Test, ASTM D638 type I (ASTM, 1998)
   ii. Flexural Test, ISO 178 (ISO 1990)

1.6 Expected results

There are few researches has been carried out on this upcoming technology. Especially in FDM concept and study about the multiple extrusions. Flashforge or Markerbot machine will using in this study that included with the multiple extrusion and combination of two different materials. Hence this study will be carried out something input for mechanical properties and the objective will achieve.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

According to the report, 3D printers, a category RP machines that is less more expensive to buy and maintain also used by individual, played an important role in 1999's growth [4]. Unlike most of the conventional manufacturing processes, RP part is produced by adding material instead of cutting it away. After years of developing of Rapid Prototyping techniques, current research is focus on improvement of RP processes and development of new, low-cost, durable, high strength materials. FDM was developed and patented in the year 1989 by Scott crump. Immediately after in 1990, he then setup Stratasys, a company which now specializes in manufacturing of additive fabrication machines for direct digital manufacturing. In 2007, almost half the amount of all fabrication systems worldwide was supplied by Stratasys making it a consecutive 6th time market leader. FDM, in its working is quite similar to other rapid prototyping systems in which a STL file is fed into the fabrication machine which then builds the model layer by layer [5].

There are many type of the machine RP technique one of them is FDM. Research of FDM can split into three types of main categories: the novel applications, the material and the system improvement [6, 7]. The rapid and most majority of system improvement are software based and related to tool, slicing and part optimization [8]. The basic mechanical system used for FDM has changed

widely since its inception in 1980's and consists of three Cartesian linear actuators, an extruder and temperature control [9].

Technology RP use a single raw material for model is usual in RP technology but recently the Multiple material some research group are developing and improving their RP system such as MarkerBot machine that can enable to make a 3D model with two colors, but creating a 3D model that works in this way is still fairly tricky.[10]. Recently the developing of FDM machine that use a dual extrusion and two material is widely improving, such as MakerBot-Replicator-2X, Markerbot-replicator ,Leapfrog BV Xeed, leapfrog BV Creatr Dual Extruder ,Flash forge Creator 1 and others. These machines are developing that had a dual extruder and can print two of material.

Very little research work has been published on the advancement dual material printing and multiple extrusion heads. W.K Chiu and S.T Tan paper study about the multiple material objects from Cad representation to data format for rapid prototyping. This paper proposes a scheme for representing multiple material objects in a CAD system [11]. N.A. Langrana, on her paper had describes a process planning method for a virtual simulation system (VSS) of FDM in RP. In this system, people can check or test a variety of the RP process parameters to make the best selection of multi-material tool-path and other parameters [12].Others paper by David Espalin, Jorge Ramirez, Francisco Medina, Ryan Wicker study about the Multi-Material, Multi-Technology FDM System, this study is using the two FDM machine that was modified and use LabView to control fabrication process and FDM motion software as an interface to control pneumatic slide. An FDM machine builds parts by driving a thermoplastic filament 1.59mm diameter into a heated liquefier and extruding a semi-molten polymer fiber through small diameter nozzle 0.127 to 0.330mm. This study successfully demonstrated the fabrication of discrete ABS-ABS parts; much work is required to fabricate using four extrusion tips. This study successfully demonstrated the fabrication of discrete ABS-ABS .The dissimilar material is the recommendation for other research. [13]

2.2 Multi-Material, Multi-Technology FDM System

The development of multi material with dual extrusion is new method in this field of FDM system. Dual extruders allow for printing with a dissolvable support material like PVA. Being able to print with water soluble material means your robot could print entire mechanical devices complete with moving pieces. Different extruded materials, such as ABS and PLA plastics, tend to have different physical and mechanical properties. ABS tends to be more flexible and PLA tends to be more rigid. A 3D printer with dual extrusion can combine the two plastics into a single object that is both flexible and rigid, with the extruders simultaneous it allowing the printer to print two objects, one with each extruder, at the same time. There is different type of fused deposition machine that build for different applications. For this project Flashforge machine are mainly machine that will be used in this experiment.

2.3 Flashforge Creator X 3d printing machine

The Flashforge Creator is an improved version of the open-source MakerBot Replicator 1, and comes equipped with a dual extruder. That means it can print in two colors or types of materials. It has a build volume of 9 x 6 x 6 in (22.5 x 14.5 x 14.5 cm). This volume is defined by the size of the build plate and the amount of travel of the vertical, or z-axis, motor. The Flashforge keeps its extruder head at a constant level, and the build platform travels down as the object is built, which I felt was a good design for accuracy.

The published specifications are a build nozzle diameter of 0.4 mm, vertical step of 0.01 – 0.03 mm, a vertical resolution of 2.5 microns, and a horizontal resolution of 11 microns.[14] This 3D Printer has become available thanks to open source technology. With an improved design and at less than two thirds the price of the original, it is the best value fully capable Dual Head 3D printer on the market.

The Creator Dual Head 3D Printer uses open source ReplicatorG or MakerWare controlling software which is used to control the MakerBot Replicator,

Thing-O-Matic, CupCake CNC, RepRap and other generic CNC machines. With further improvements from the original design including improved electronic circuitry, a higher 0.1mm Z resolution, a refined MK8 print head and the addition of a cast aluminium heated build platform, allowing for printing in ABS and PLA plastic.

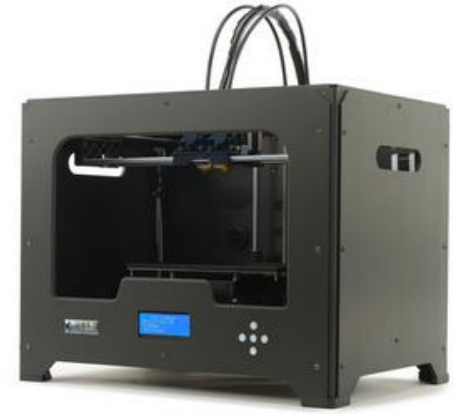
This Machine has two extruders, providing the possibility to print with two colors or two different materials at the same time. This also means that possible to print with ABS filament and with soluble PLA or PVA filament that can serve as support material. The plastics PLA and PVA are both materials that can be dissolved and do not leave any marks on the surface of your print. This machine is easy to install, large print size, fully assembled, heated print bed and dual extruder option. The images specification and parameter of the machine shown in Table 2.1 and Figure 2.1 below.

Table 2.1: The Flashforge Creator parameter

ABS	PLA
Print Temp= 230°C	Print Temp=230°C
Temp bed =110°C	Temp bed= 60°C
Size diameter=1.75mm	Size diameter =1.75mm
Nozzle diameter=0.4mm	Nozzle diameter =0.4mm
Extruder= 0.1-0.3 mm (adjustable)	Extruder= 0.1-0.3 mm (adjustable)
Layer height=0.1mm	Layer height=0.1mm
Nozzle heat=230^{o}c	Nozzle heat=230^{o}c
Density=0.1	Density=0.1

2.3.1 Machine features

Table 2.2: Specification of the Flashforge Creator X 3d printing machine

Specifications- 	
Print volume / build size (X,Y,Z)	4.9 litres (225x 145x150)mm
Frame size (X,Y,Z)	320x467x381 mm
Resolution (Z-AXIS)	0.1 - 0.3 mm
Accuracy (Theoretical positioning resolution)	Z axis 0.0025, XY axis 0.011 mm
Print Speed	40-150 mm/sec
Total mass	13 kg
Nozzle diameter	0.4 mm
Nozzle Flow Velocity	24 cc/hr
Recommended Nozzle Materials	230 ℃
Filament Diameter	1.75 to 1.8 mm
Filament Material	ABS, PLA, PVA, HIPS, Nylon etc
Slicing Software	ReplicatorG / MakerWare
OS Support	Windows xp, Windows Vista, Windows 7, Linux, M ac OX

Print without PC	Yes with SD card (included) or USB link
Heated Bed included	Yes up to 120 ℃
Power Consumption	220V, 300W
Extruder Heads included	2

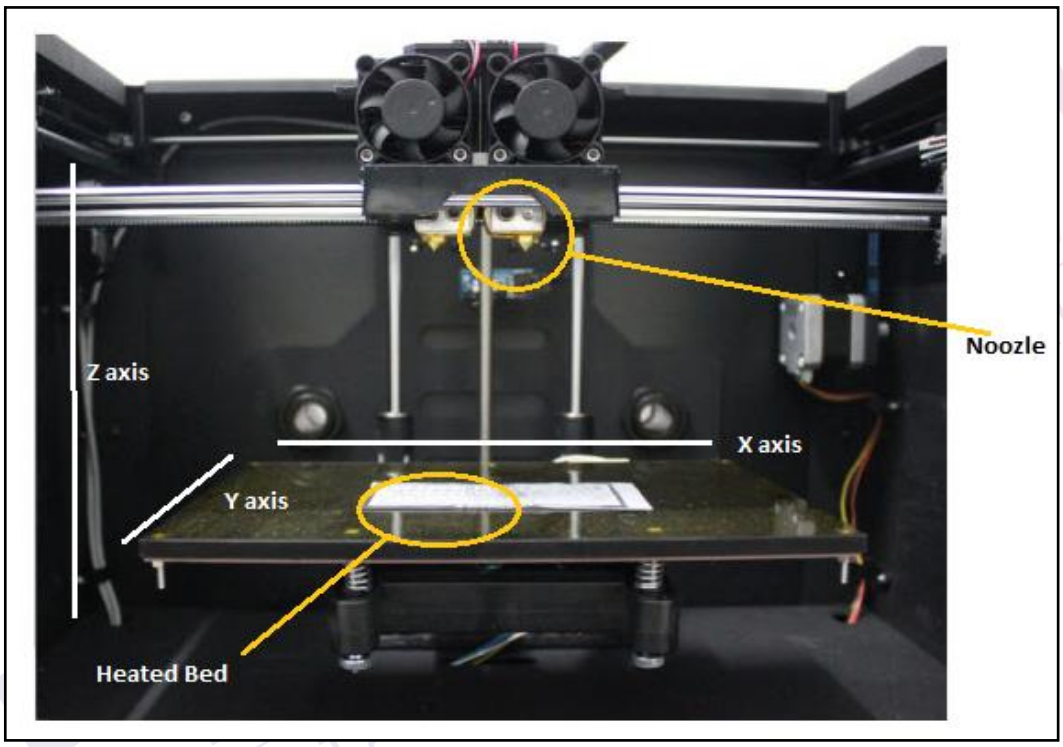


Figure 2.1: Images of flashforge machine

2.4 Software and configuration

There are many software that we can used in connected with this machine. One of the free software called repeater host. This includes Slic3r, program that produce the G-code for printer from STL file. Repetier is used to control the printer ad make the prints. Other than that this machine is used professional Simplify 3D software that has a rapid and accurate slicing engine. In this experiment I were choose the

markerware software Figure 2.2, it's because this software it easy to understand and to learn for the new comer.

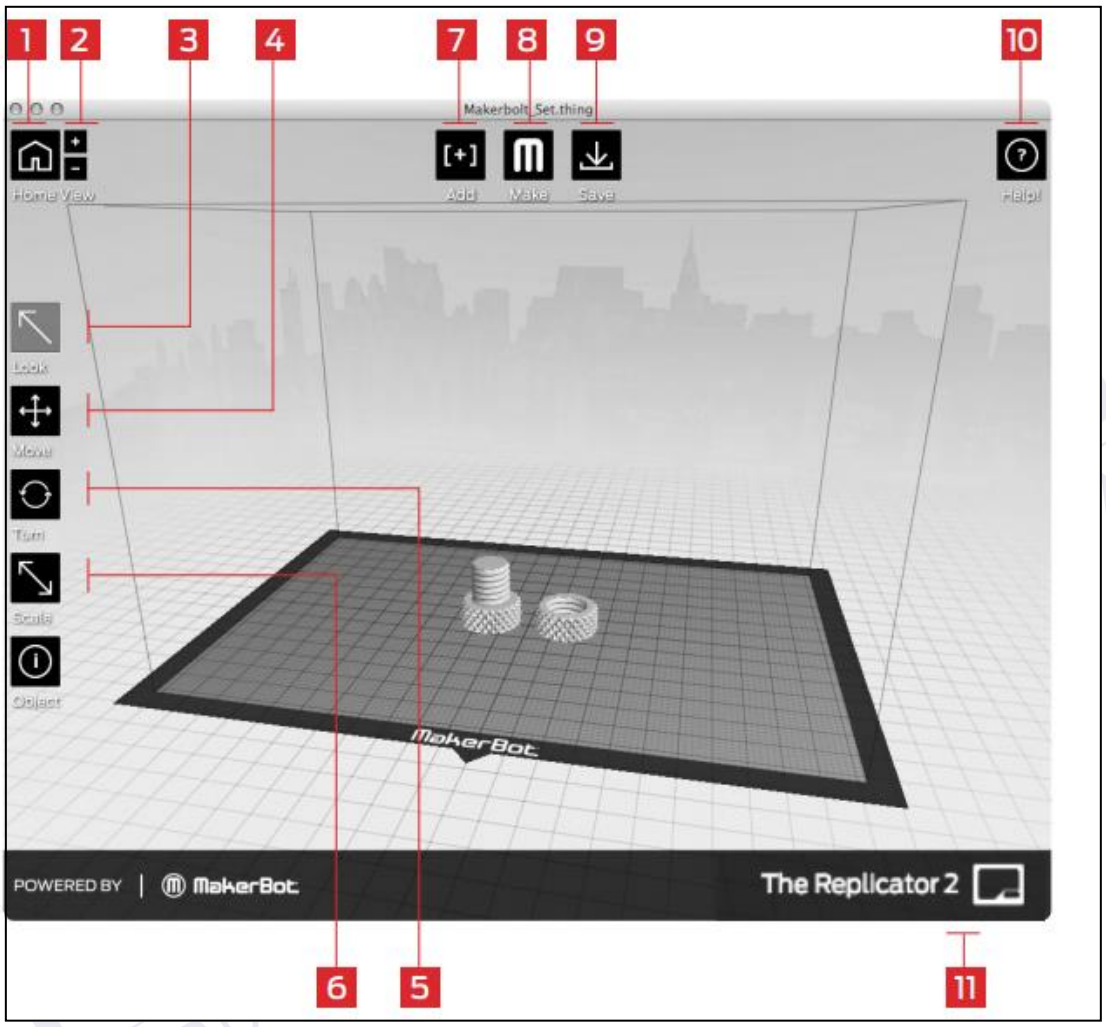


Figure 2.2: Markerware software image

1. CAMERA HOME
2. +/- Zoom in and out.
3. LOOK
4. MOVE
5. TURN
6. SCALE
7. ADD
8. MAKE IT
9. SAVE
10. HELP
11. STATUS BAR

2.5 Material selection

The selection of the material is using the main material that use for flashforge Creator. ABS and PLA will be main material that use in this study. James Spain in his study said that the printing a PLA component on an ABS raft proved to be the most consistent configuration throughout the project. [15]

ABS has a higher strength boundary than PLA, making it possible to perfume a surface treatment with sandpaper, acetone or even drill holes in print. ABS filament is available in a wide range of colors. It is a plastic that is non-soluble and can easily be treated with sandpaper.

PLA is a material that reduces the chance of the separate layers of your print to split. It is also excellent as support material, because it leaves no marks on your surface after dissolving it. PLA filament is available in a wide range of colors. It is a plastic that is soluble in sodium hydroxide and is mainly used as support material and to print big objects. The specification parameter of material ABS and PLA is shown in Table 2.3 and Table 2.4.

Table 2.3: Specification Parameter of material ABS and PLA

ABS	PLA
Print Temp= 230°C	Print Temp=210°C
Temp bed =80°C	Temp bed= 60°C
Size diameter=1.75mm	Size diameter =1.75mm
Nozzle diameter=0.35mm	Nozzle diameter =0.35mm

Table 2.4: Properties of ABS and PLA

Item	Unit	ABS	PLA
Tensile strength	Mpa	59	45
Strain to break	%	3	15
Flexural strength	Mpa	85	63
Flexural modulus	GPa	2.9	2
Specific gravity	-	1.2	1.1
HDT	oC	56	102
Izod impact	Kgfcm/cm	3.4	8

2.5.1 Experimental out line for ABS and PLA material

The first objective is to analyze the capability of assigning two materials in one sample or product. Analyze the ability of assigning two materials is more to STL file process, which is to study that any different STL step for two material versus the single material concept. As we know all the RP techniques employ the same basic five step process. The steps are as follows:

i. Create a CAD model of the design.

ii. Convert the CAD model in to STL format.

iii. Slice the STL model in to thin cross sectional layers

vi. Construct the model one layer atop another.

v. Clean and finish the model.

CAD model design is step that prepared the object built using the CAD software example solid work, Auto CAD etc. These step is tend 3-D model to more accurate then sketch and hence produce the good result while printing. The process is same for all RP type concept built.

Next is conversion to STL format. This step is the most important because it establishes the consistency the STL format that has been adopted as a main standard for RP. This STL format is represents a three-dimensional surface as and assembly of planar triangles, this file is contains the coordinate of vertices and direction of the

outward normal of each triangle. File with complicated require more time to process and build, so the accuracy balanced with manageability is important to produce a useful STL file .This format also identical for all's RP techniques.[16]

A preprocessing prepares the STL file to be built. The program is available to adjust the size, location and orientation. Build orientation is important for some cases, part orientation practically determine the amount of time required to build model.

Next go through to the actual step hat construct the part. It depend on the machine and the technique that be used. Most machines are autonomous. Lastly is post –processing. This involves the removing and detaching the material support. Some surface treatment can improve the appearances and durability of model.

Insight is the one program software usually uses to process an STL file and send it to the FDM Machine for single material shown in Figure 2.3:

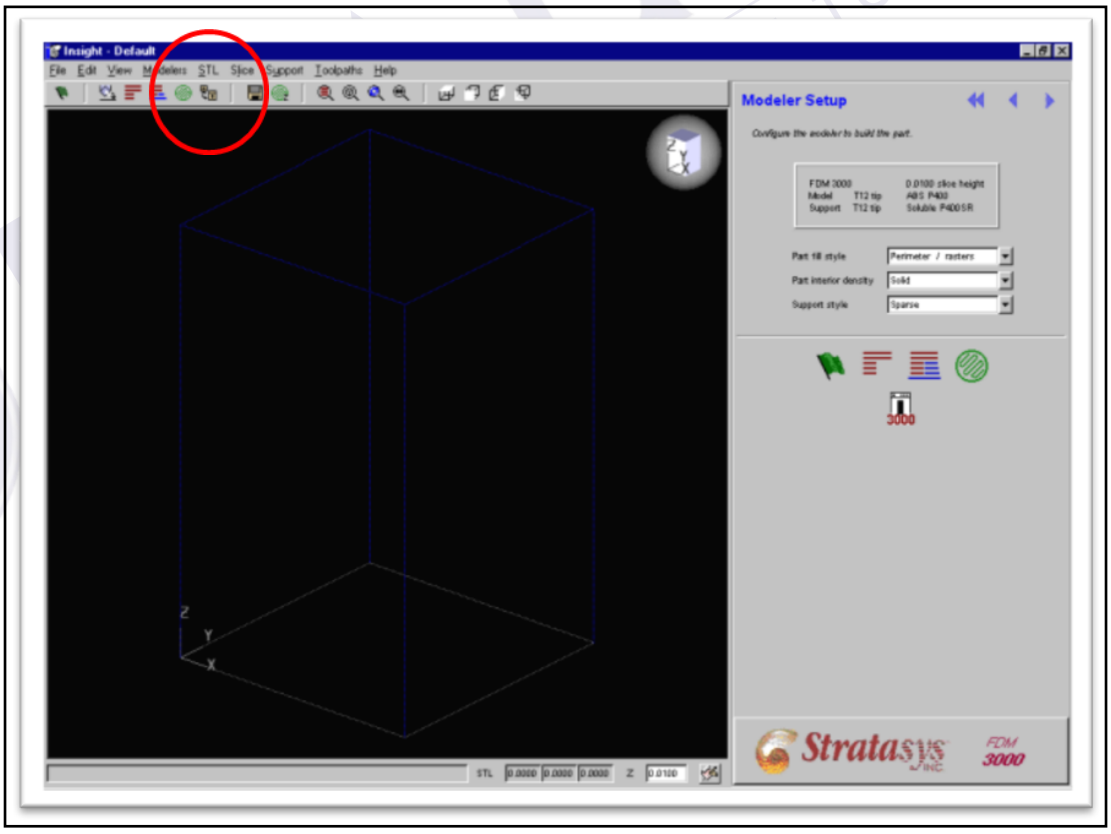


Figure 2.3: The insight software for single material and extruder

From the File menu, open your STL file. If you are doing your license part, open FDM key license. STL in the FDM user folder on the Users drive. Your part will appear in the FDM coordinate system as a shaded model. You can look at it from different angles by manipulating the small coordinate system at the top right of its window. From the STL menu, also we can choose "Automatic Orientation". This command lets you specify the method by which you want Insight to search for possible orientations. You can then select your favorite orientation from the options it suggests.

Hence for, printing a part in multiple materials the software allows use of different colors for regions of the part. In taking the concept a step further, materials can be developed for extrusion in any kind of printers so their physical properties can be exploited.

In order to use the multi material printing feature, three STL files need to be generated in CAD software:

- Combined part STL file. This is used to generate the raft and any support material tool path.
- Part material A STL file. This is used to generate the tool path for the extruder containing material A.
- Part material B STL file. This is used to generate the tool path for the extruder containing material B.

This mean that every of solid that you used for different colors or material you need the different STL file name. Other example you have three solid then you need the three of STL file name shown in Figure 2.4.

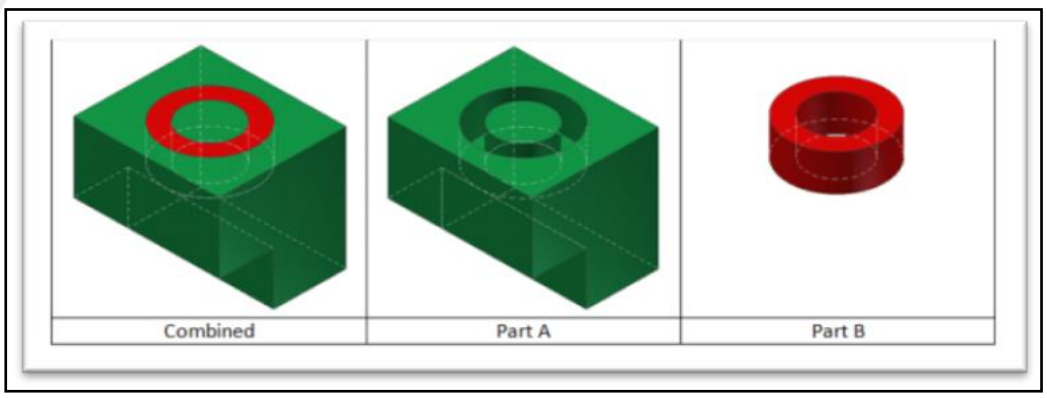


Figure 2.4: A STL file for two color and part

For another example is the two color earth model. It consists of two .STL model files. One is for the "water". The other for the "land" shown in figure 2.5 to 2.7 below

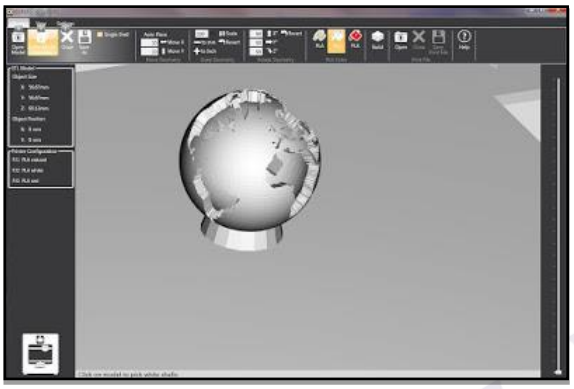


Figure 2.5: Water STL file

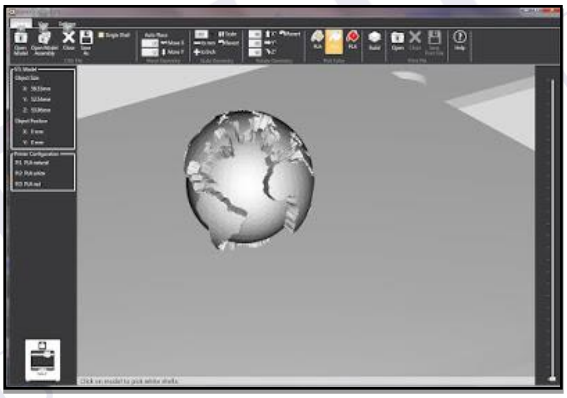


Figure 2.6: Land STL file

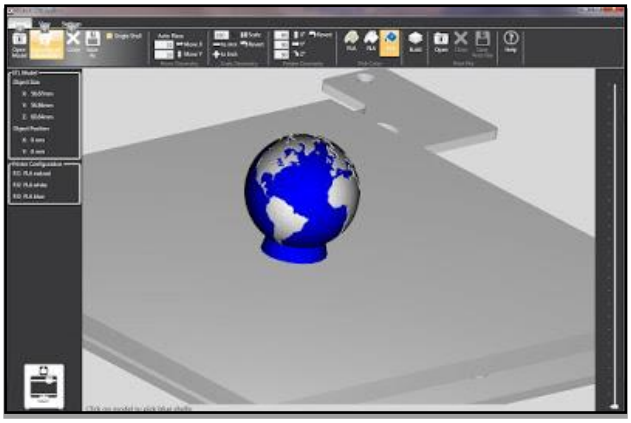


Figure 2.7: Combine with colors assigned

Therefore relate to my main machine that I will use is a leapfrog Creatr Dual extruder, it is possible to print with two different materials and color at the same time too. Firstly to be able to print in multiple colors you will first of all need the latest version of Slic3r.

The same trick to printing in two different colors like other machine is that two different STL files we need, one for each color. These two files have to be combined into one file by Slic3r. Follow the instructions below:

- Open Slic3r
- Go to submenu “File”
- Select “Combine multi-material STL files” as shown in figure 2.7 below

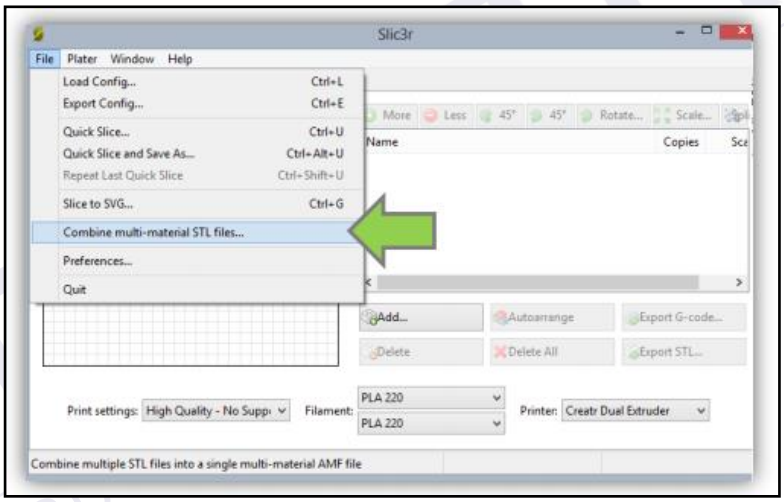


Figure 2.7: The combine of multi-material STL file

A window will then pop up for you to browse for your two STL files. Browse to select and open STL file for the first color. When you have done so, a new similar window will pop up in which you have to browse to, select and open STL file 2.

After selecting and opening the second STL file a similar window will pop up again, allowing you to add a third file and file and this continue for as many files desired, but since there only two different extruders in the printer, two files is the maximum amount you wish for so therefore press cancel.

Now that the files which are to be combining have been select a new window will pop up to save the new combined file. Browse to the location you wish to save

this file. Give it name and save it. It will be saved as an ".amf file". Then load the ".amf file" in Repetier Host Leapfrog software just like you would do a regular STL file. You are now good to go to start multi-color printing by treating this file just like you would treat any STL file.

2.6 Conclusion

The conclusion that I can make is that the single extruder or material or color or part just need STL file for one file, but for the multi material, extruder, color or part need two or more STL file name, before the STL file before going to Slice STL model process in to thin cross sectional layers. Since the machine have only two extruder that mean it's only can use two different material and color in the same time.

2.7 Objective II

To evaluate the joining of two different of material in one product or sample. This experiment is more to different setting of path .The parameter will related with the mechanical properties experiment parameter that focusing in strength of joining, which is its more to see the combination of ABS and PLA with different type of joining. The other specimen will use for this experiment. This experiment will discuss details in chapter three.

2.7.1 Measure the mechanical properties

PLA (Polylactic Acid) is easiest material to work with when you first start printing. PLA is a biodegradable thermoplastic that has been derived from renewable resources such as corn starch and sugar cane. Therefore from the environmentally

PLA is friendly and very safe to work. PLA also have a very sharp glass transition point so if you use a fan to cool it and set very quick to solid. .

ABS (Acrylonitrile butadiene styrene) is also easiest material to work with when you start 3D printing. ABS is an engineering polymer commonly used to produce car bumpers due to its toughness and strength. PLA and ABS does not require any curing or post-production treatment, however should you wish to, PLA and ABS can be sanded and coated with automotive spray filler. PLA and ABS can be painted over with acrylic paint.

ABS has a higher strength boundary than PLA, making it possible to perfume a surface treatment with sandpaper, acetone or even drill holes in print. ABS filament is available in a wide range of colors. It is a plastic that is non-soluble and can easily be treated with sandpaper.

PLA is a material that reduces the chance of the separate layers of your print to split. It is also excellent as support material, because it leaves no marks on your surface after dissolving it. PLA filament is available in a wide range of colors. It is a plastic that is soluble in sodium hydroxide and is mainly used as support material and to print big object.

A few of study on PLA material compared to ABS in mechanical properties. B. Eng. Enno Ebel and Prof. Dr. rer. Nat. Thorsten Sinnemann on their study, to evaluate the influential factors by using the PLA and ABS material and using different pattern of each sample. The PLA sample is have largest yield strength then ABS and the end of the thesis in conclusion, from the point of view in that study, PLA may play a more prominent role in the future then the ABS. [17]

Shinji Ochi on his paper describes about the cultivation of kenaf /PLA that fabricated using kenaf fiber bundles and an emulsion type biodegradable resin, which contained fine particles approximately 5 micron meter in diameter suspended in aqueous solution. Tensile strength of kenaf heat at 160^{o}C for 60 min did not decrease. Thus 160^{o}C is highest fabrication temperature that does not affect strength. [18]

Dietmar Drummer, Sandra Cifuentes-Cue´llar and Dominik Rietzel, they use of PLA and tricalcium phosphate (TCP) as resorb able composite is state of the art in tissue engineering and surgery. Purpose of this paper is to study the processing conditions and performance of part manufactured with FDM machine. , the paper

shows that by thermal analysis it is possible to identify major influence on processing and part properties. [19]

Study on ABS material is widely doing in FDM machine by peoples. The mechanical properties is one of the rapidly issues that study by researchers and students such as Ashutosh Chouksey that study in National Institute of Technology Rourkela by his paper that study the parametric optimization of fused deposition modeling process using response surface methodology .In his study he choose the three the main parameter that a lot of researcher focused, layer thickness, orientation build and raster angle. [20]

Sood et al study about the effect of orientation layer thickness, raster angle and raster width, raster to raster gap is studied with help of Taguchi method on dimensional accuracy. Significant factors and their interaction are found out using the Taguchi method. The optimum setting of the parameters are found out so that all the three dimensions show minimum deviation from actual value setting. The other research on his study on parameter orientation layer thickness, raster angle, air gap and raster width effect on mechanical strengths, like tensile, flexural and impact strength. The surface plot is analyzed to distortion between layers. . [21]

Since my main objective is to fine the mechanical properties especially in tensile strength, I have make a literature review in ABS tensile strength more detail as show in Figure 2.3 below:

2.8 Literature review

Table 2: Literature review summary

No	Title	Type of Material	Parameter	Result (Tensile Strength)
1	**FDM Part Quality Manufactured with Ultem*9085**	Ultem*9085	Build of direction: 1) X-direction 2) Y-direction 3) Z-direction	Comparison of average values from tensile test: 1) X-direction= 63.25MPa 2) Y-direction= 45.87MPa 3) Z-direction= 40.75MPa
2	**Optimization of Fused Deposition Modelling (FDM) Process Parameters Using Bacterial Foraging Technique**	ABS P400	1) Layer thickness (0.1270mm, 0.1780mm, 0.2540mm) 2) Orientation (0.0º, 15.0º, 30.0º) 3) Raster angle (0.0º, 30.0º, 60.0º) 4) Raster width (0.4064mm, 0.4564mm,0.5064mm) 5) Air gap (0.0mm, 0.0040mm, 0.0080mm)	Functional relationship between process parameters and tensile strength for FDM has been developed using response surface methodology for prediction purpose. When the value of tensile strength is 174.3177Pa; 1) Layer thickness = 0.1318mm 2) Orientation = 9.6100º 3) Raster angle = 59.937º 4) Raster width = 0.4196mm 5) Air gap = 0.0074mm

3	**Improving Tensile Mechanical Properties of FDM- Manufactured Specimens via Modifiying Build Parameters**	ABS	1) Raster angle (0º/90º, 30º/-60º, 45º/45º) 2)Build orientation (xyz)	The highest average Young's modulus achieved was 1816MPa that was obtained using a 0º/90º RA with the visual feedback method.
4	**Material Characterization of Fused Deposition Modeling (FDM) ABS by Designed Experiments**	ABS P400	1) Air gap (0.0 inch, -0.0020 inch) 2) Road width (0.02 inch, 0.039 6inch) 3) Model temperature (270ºC, 280ºC) 4) ABS color (Blue, White) 5) Orientation of Rasters (Transverse, Axial)	Measured tensile strength of the typical crisscross raster (45ºC/-45ºC) and cross raster (0ºC/90ºC) were 17MPa and 19MPa.
5	**Process Parameters Optimization of FDM Process and Application of Taguchi Approach and ANN- The Review**	ABS	1) Air gap (solid fine, Sparse, Double wide) 2) Raster angle (0º, 45º, 60º) 3) Raster width (0.305mm, 0.655mm, 0.980mm) 4) Layer thickness (0.178mm, 0.254mm, 0.305mm)	The effect of FDM parameters on Tensile and Flexural strength of test specimen are layer thickness, orientation angle and raster width. Tensile = 29Mpa
6	**Analysis of Bonding**	ABS-M30,	Building parameter	The highest of ultimate stress

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